Sandia BOS Testing

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Surge Testing Can Improve Reliability

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Background

Nearby lightning can result in surges on ac and dc inverter power wiring and diagnostic cables that have the potential to shorten inverter lifetime. Additionally, load switching can result in similar pulses on ac lines. Placing protection devices at the point where the lines enter a building best mitigates the effects of these surges. Since this is frequently not accomplished, it is also advisable that PV inverters have internal surge protection.

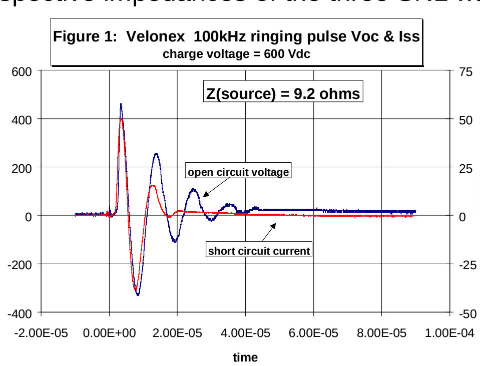
IEEE C62.41-1991 and C62.45-1992 discuss low-voltage equipment test conditions and methodology in detail. Inverters can be located outside (i.e. location category C); however, location category B, which includes the building service entrance, has been selected by Sandia National Laboratories (SNL) as the most appropriate location category for typical PV inverter evaluations. Two pulses are described in the IEEE documents; 1) a .5 µs risetime -100 kHz ring wave (figure 1), and 2) a 1.2 x 50 µs (risetime x pulse width) –8 x 20 µs combination wave (figure 2). The combination waveform is a 1.2 x 50 µs voltage pulse into an open circuit and an 8 x 20 µs current pulse into a short circuit. The energy in the applied pulse is determined by the pulse shape and the charge voltage applied to capacitors inside the surge generator. Charge voltages for location B are variable up to 6 kV. Surviving these pulses does not ensure that an inverter would survive nearby lightning. In fact, the levels of the pulse are negotiable by the parties involved in the evaluations. Surviving the pulses does confirm a certain desirable level of hardening of the inverter.

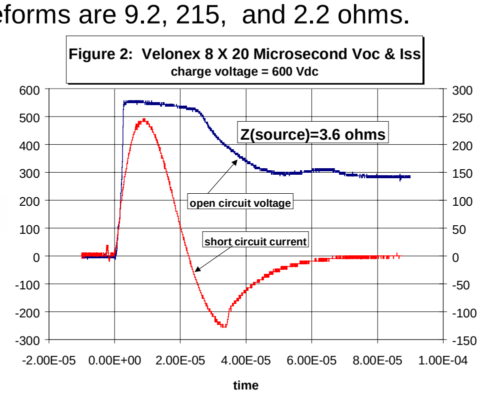
Objective

This brief defines a test methodology used by SNL to establish the level of surge pulse that could result in damage to low voltage equipment, up to the limit as defined in IEEE C62.41. Criteria for successful completion of a test are 1) no failures at agreed-to open-circuit surge generator voltages and 2) no impairment of anti-islanding circuitry. Note that this is a design evaluation test and that the stress to the inverter is not limited as it would be in a screening or qualification test.

Description of Test Configuration

A Velonix Model 587 high voltage surge generator and a Velonex V-2734 isolation unit are used in the SNL evaluations. An additional 1.2 x 50 µs waveform is available to pulse high impedance circuits. If, as is typical, the inverter inputs have low impedance then the 8 x 20 µs pulse, defined for a short circuit, is the more severe stress. The respective impedances of the three SNL waveforms are 9.2, 215, and 2.2 ohms.





Test Philosophy: The test philosophy includes the following elements:

1. Incremental Application of Stress. Pulses result from the discharge of a capacitor through the impedance presented by the inverter. Thus the actual output voltage may differ significantly from the capacitor charge voltage. The initial charge voltage is chosen as 500 volts. Subsequently, to determine the level of hardness of the equipment under test (EUT), the charge voltage is incremented in steps of 1000 Vdc from 1 to 6 kV. As the charge voltage is increased it is probable that a protecting

device will suddenly be activated. This may result in less coupled energy at higher voltages than at lower voltages where the protective device is still inactive. Thus the EUT may prove to be more susceptible to a lower or intermediate voltage than a higher voltage.

2. Dual polarity testing. Both negative and positive pulses are applied. Dual polarity pulses are obtained by reversing the connections between the 587 and the V-2734 units.
3. Repetitive Pulses. High voltage pulses can incrementally weaken components with no apparent damage after the initial pulse. Thus for an inverter which survives all voltage increments five pulses will be applied at the highest charge voltage level. This will further increase confidence in hardness. Repetitive pulses are at least 30 seconds apart.
4. Unpowered Evaluations. A powered up EUT provides greater potential stress to components because breakdowns due to surges can be exacerbated by the large amount of energy available from either the dc or ac lines. This extra current, supplied by the equipment under test is referred to as “follow” current. Since the stress is lower in the unpowered EUT case, unpowered evaluations are completed prior to powered up evaluations.
5. Powered Evaluations. Powered evaluations are necessary because of the likelihood of “follow” current and because of the need to evaluate the survivability of anti-islanding features of grid-tied inverters. Because of the possibility of latent damage to these critical circuits, an anti-islanding test should always be conducted after each significant level of surge testing. Filters are required between the EUT and other power sources to protect the power source and to present a high impedance to the surge.
   a. Ac input lines. The Velonex V-2734 isolation unit is used as designed to provide series coupling and the required isolation. Current is limited to 20 amperes.
   b. Dc input lines. Where possible the Velonex V-2734 is used; however, the Velonex V-2734 is limited to 50 volts dc and thus can not be used for isolation for some inverters. For these, isolation is provided with a custom filter. A low inductance capacitor is used to couple the pulse to the EUT.
6. Evaluation of Transfer Functions. A transfer function that defines the current, which passes through the protection circuitry, is useful for designers. Care must be taken to avoid significantly changing the circuit configuration or damaging instrumentation. This is accomplished by monitoring the signal with a current probe. The monitored wire is wrapped in mylar to prevent arcing and centered in the current probe, to minimize capacitive coupling. The signal from the current probe is fed to a battery-operated oscilloscope and isolated from ground.

   The transfer function also provides a means for detecting flash-over or breakdown in the applied signal. Initially the signals are applied at low voltage where no possibility of flashover exists. As the charge voltage is increased, the coupled signal envelopes will be identical and will scale in magnitude unless a nonlinear effect occurs. Thus a change in the coupled signal envelope or a failure to scale linearly implies that a nonlinear event has occurred.

Discussion

There have been reports of reduced inverter reliability as a result of nearby lightning. The inclusion of lightning mitigation components in PV inverters can improve inverter reliability. The evaluation techniques at SNL enable manufacturers to ensure that the inverter is hardened to a level as discussed in IEEE C62.41.

For More Information:

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